<u>RTCA Special Committee 186, Working Group 3</u>

<u>ADS-B 1090 MOPS, Revision A</u>

<u>Meeting #12</u>

Non-Poisson Behavior

Presented by William Harman

SUMMARY

The simulation used at Lincoln Laboratory for Extended Squitter performance assessments models ATCRBS fruit reception times as a Poisson process. This model has now come into question, and appears to be inappropriate. As a result the assessments have been pessimistic.

Non-Poisson Behavior

William Harman

In the spring of this year, a team effort was made to assess Extended Squitter performance in Europe. The work has been completed, and a final report was issued in June [ref. 1]. Performance results, for the enhanced reception techniques, were generated independently by three organizations, Lincoln Laboratory, APL, and Eurocontrol. Comparing the results, it was noted that the Lincoln and APL results differ noticeably, although both were based on the same formulation — that either a position squitter or a velocity squitter reception in a 12 second period would count as a surveillance update (whereas the Eurocontrol analysis used a more conservative basis). Specifically, in a future high density environment (183% of the current maximum), the APL results show performance to 50 NM range, whereas the Lincoln results indicate performance to 38 NM range.

At the time of the final report, we were not able to identify the reason for this difference, but have continued to consider the question. A likely explanation involving detailed timing behavior has come to light.

For assessing the performance of Extended Squitter, Lincoln Laboratory is using a pulse-level simulation, whose output gives reception probability as a function of received power level. The input to this simulation is a fruit model, which defines received ATCRBS and Mode S fruit rates and their power distributions. Given the fruit rates, the simulation models the fruit arrival times as a Poisson process.

A Poisson process is the simplest statistical model for random event times having a given average rate. In this model, the likelihood of any one reception is constant throughout time (not peaked), and all events are independent. In contrast with this, it was suggested by Al Cameron (TASC) that fruit arrival times are significantly different from the Poisson model. He came to this conclusion by studying results from a detailed simulation, developed by TASC, of the 1030/1090 interference environment in Los Angeles. He documented the TASC simulation results showing non-Poisson behavior in Reference 2 along with an explanation of the physical mechanisms that could cause this effect. The TASC results apply to airborne receptions using an omnidirectional antenna.

TASC Results

Figure 1 shows one of the main results from Ref. 2. This is a histogram showing the distribution of the number of fruit receptions in 100 microseconds, and comparing the TASC simulation results with the corresponding Poisson behavior. Note that the TASC distribution is entirely different. Reference 2 gives results for a number of other cases, and they all show the same striking difference as in this figure.

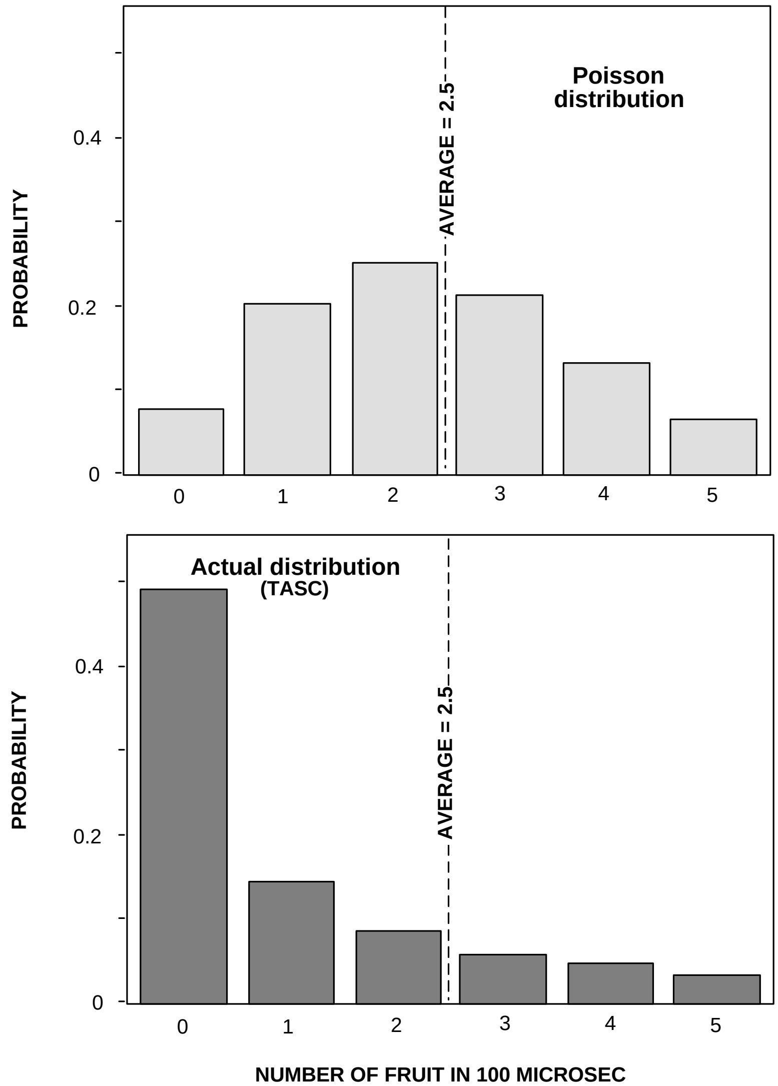

Figure 1. TASC timing results compare with Poisson.

The difference can be described by saying that a Poisson distribution has a preponderance of occurrences near the mean value, which is 2.5 overlaps in this case. The most common value is 2 and the second most common value is 3. But in the actual distribution, zero is the most common value. In other words, the fruit reception times are correlated, such that it is common to have multiple fruit overlaps and also common to have zero receptions within a 100 microsecond window.

In the context of Extended Squitter reception, this bunching of fruit is a beneficial condition, because it results in higher probability of getting a signal reception without any overlapping fruit.

<u>Mechanism</u>

The mechanism causing this non-Poisson behavior is discussed in Reference 2. One possible cause is the mainbeam geometry of the ground based radars that trigger fruit transmissions, illustrated in Figure 2. The fruit from all aircraft within the beam at one time will arrive at an airborne receiver closely bunched in time. Note that for any aircraft located on a straight line between the radar and the receiving aircraft, the fruit arrivals will be exactly simultaneous because the sum of the propagation time for the interrogation and the propagation time for the reply will be equal. When the interrogating beam is somewhat away from this line, as illustrated here, the fruit receptions will not be exactly simultaneous, but will be quite close. An ellipse drawn to scale in the figure shows the aircraft locations for which the additional propagation time is only 100 microseconds. Fruit from any aircraft within this ellipse will be received within 100 microseconds of the minimum delay condition (aircraft on the straight line).

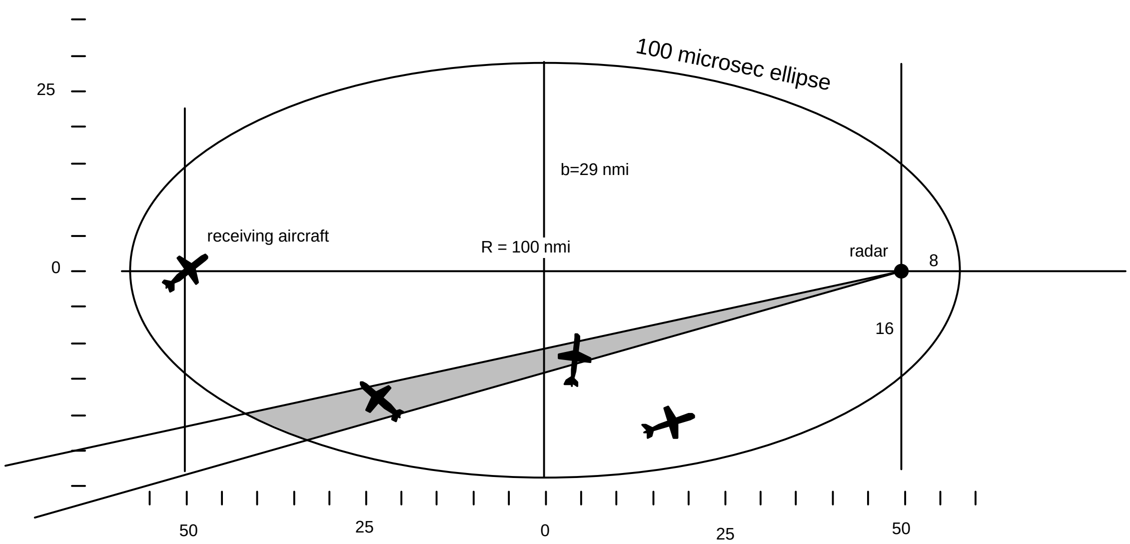

Figure 2. Geometry causing bunching of ATCRBS fruit.

We can make a rough estimate of the number of bunched fruit as follows. Suppose the range from the radar to the receiving aircraft is 100 NM, and suppose the aircraft density = 0.2 aircraft per square NM, beamwidth = 5 degrees, the range from the radar to the ellipse = 80 NM, as in this illustration. Then the average number of aircraft within the shaded area is

Average = (density) * pi * (80 NM)^2 * (5/360) = 6 aircraft

Therefore a single interrogation will trigger 6 ATCRBS fruit all within 100 microseconds. This is a large number when compared with, for example the average of 2.5 in the example in figure 1. In that scenario, the average from all aircraft and all interrogators is 2.5, so a bunch of 6 from a single interrogator is far above average.

Figure 3 shows this behavior in another manner. For a single radar having a typical interrogation period of 3300 microseconds, this shows that many of the fruit replies are received within a small portion of the period.

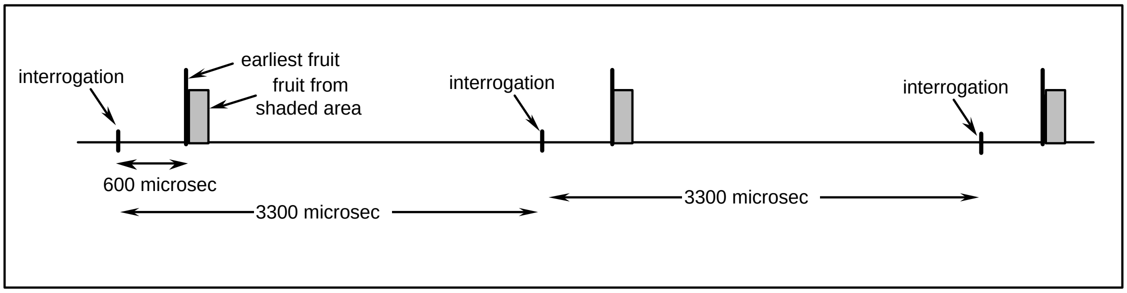

Figure 3. Interrogation and reception timing.

After discussing this with Al Cameron and others I have come to realize that the total behavior of all fruit receptions will vary from Poisson behavior in degrees depending on the TCAS contributions and other factors. ATCRBS fruit triggered by ground based radars is controlled by the product of the number of radars and the number of aircraft. If the total is caused by a small number of radars and a large number of aircraft, then the timing behavior will be more peaked and less like Poisson. Conversely, if the total is caused by a larger number of radars and a smaller number of aircraft, then this will tend to cause the reception timing to be more like a Poisson process.

Conclusion. Based on these considerations, I conclude that the non-Poisson effects are considerable, and that the performance assessments using the Poisson model were significantly inaccurate, and pessimistic relative to the actual system performance. This could account for the difference between the APL results and Lincoln's results for Europe in the future, and probably means that the APL results are more correct.

REFERENCE 1. "1090 MHz Extended Squitter Assessment Report," June 2002, FAA and Eurocontrol.

REFERENCE 2. A. G. Cameron, "The 1030/1090 MHz Interference Simulator Technical Description and Initial Results," TASC Technical Report, TR-9454-02-01, 27 April 2001.